REPORT

Scope of Work for the Initial Assessment of Aquatic Ecosystem Health in Alberta

ALBERTA ENVIRONMENT

PROJECT NO. ABC50619

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REPORT TO: **Alberta Environment**

FOR: **Scope of Work for the Initial Assessment of Aquatic Ecosystem Health in Alberta**

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INTRODUCTION

1.0 INTRODUCTION

Alberta Environment released its *Water for Life* Strategy in November 2003. The Strategy makes the following commitments to residents of Alberta:

- Safe, secure drinking water supply;
- Healthy aquatic ecosystems; and
- Reliable, quality water supplies for a sustainable economy.

Short, medium and long-term goals have been identified that are anticipated to achieve those goals. Part of the *Water for Life Strategy* involves a province-wide assessment of aquatic ecosystem health (AEH). A preliminary assessment of AEH in lakes, wetlands, streams and rivers is a target to be delivered between 2007 and 2010, while a longer-term goal is to understand the quality of surface and groundwater resources by 2014. The initial assessment will identify data gaps, help design future monitoring programs, and establish a baseline for reporting.

The goal of the present project is to develop the approach and scope of work to complete the initial assessment. This document, thus (1) provides background on approaches for defining aquatic ecosystem health, (2) reviews Canadian and other pertinent international approaches for assessing aquatic ecosystem health, (3) proposes a framework for conducting the initial assessment of AEH, and (4) develops a scope of work for the initial assessment of aquatic ecosystem health.

This document has the following sections:

- Overview of ecosystem health, and how the term can be operationalized,
- Overview of current Canadian and International approaches for monitoring aquatic ecosystem health,
- Proposed Framework for the Initial Assessment, and
- Proposed scope of work for the initial assessment.

REVIEW OF ECOSYSTEM HEALTH DEFINITIONS

2.0 OVERVIEW OF DEFINITIONS AND OPERATIONALIZING ECOSYSTEM HEALTH

It is intended that the Initial Assessment will provide a preliminary evaluation of aquatic ecosystem health. What is a healthy aquatic ecosystem? The notion of ecosystem health as an analog to human health is not new. Ecosystem health is an appealing concept because it is intuitive from a human perspective. How we define "healthy", also influences the things we evaluate (i.e., what measurement

endpoints), and how those things are evaluated. A relatively clear definition of what is considered a healthy ecosystem underpins the Initial and later assessments of aquatic ecosystem health. This section of the report, therefore, briefly overviews the concept of what a healthy aquatic ecosystem is, then proposes a single definition that provides the foundation for recommending measurement endpoints and approaches to interpreting the condition (health) of endpoints. For the purpose of the Initial Assessment, an ecosystem is considered a suite of plants, animals and other life, living and interacting, and interacting with the physical and chemical environment within a defined space (a specified aquatic environment).

There are really only two general approaches to defining a healthy ecosystem that can be operationalized. First, ecosystems may be considered healthy when the attributes of concern vary differently from what is expected of them, based on what we observe in natural areas. Karr and Dudley (1981), for example, referred to biological "integrity" as *the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition and functional organization comparable to that of the natural habitat of the region.* Ecosystems are generally considered to have integrity, then, when they are in their natural state. It has become relatively popular to use the term "Integrity", when referring to the natural state of an ecosystem (Kay, 1989; 1993; Lackey, 2001).

If an ecosystem is considered to be healthy when it is in its natural state (i.e., has integrity) measurement endpoints can include indicators of the composition of different assemblages of plants or animals, or of different ecosystem functions such as photosynthesis, respiration, and energy transfer. When "healthy" infers a natural state, then the criteria against which measurement endpoints are judged is typically based on observations made from natural areas experiencing a minimum of disturbance from human activity (i.e., reference areas). It is often difficult to find pristine reference areas, so defining what is meant as an acceptable reference area becomes a significant consideration in this approach. Natural areas exhibit variability in measurement endpoints (e.g., indicators of community composition, nutrient dynamics, etc.) both temporally and spatially. Temporal variation can include natural seasonal variation, natural year-to-year variation, and year-to-year variation due to extenuating climatic conditions or natural disturbances (e.g., forest fire). Spatial variations will be due to natural limitations imposed by physical and chemical conditions, and biotic interactions. These natural spatial and temporal variations must be considered when interpreting the "health" of an aquatic ecosystem.

The second approach to operationalizing the term ecosystem health is in reference to preferred human uses. In this case, ecosystems are considered healthy when they meet economic and aesthetic expectations of society (Calow, 1995). Aquatic environments, for example, that provide potable water, edible fish, enough fish to create a recreational opportunity, or enough water for irrigation purposes could be considered healthy, despite any deviations from a natural condition. Cash et al. (1995) argue that reliance on human needs to define a healthy ecosystem "*raises clear ethical concerns and is a direct contradiction of the "ecosystem approach"*". Regardless, some attributes of the aquatic environment must be, and are viewed in this perspective (e.g., coliform counts, mercury levels in fish tissues).

Calow (1995) and Cash et al. (1996) recognize a third option for defining "health" termed the pragmatic approach. The pragmatic approach combines societal input and scientific information to decide what

any particular ecosystem should look like. As a consequence, the basis on which an ecosystem is judged to be either healthy or unhealthy may vary regionally or over time.

From an operational perspective, a "healthy" ecosystem, has attributes (measurable endpoints) with observable conditions falling within acceptable limits. "Limits" are typically numeric or narrative criteria established on the basis of values observed in reference locations (from an "integrity" or natural perspective), or on the basis of values required to ensure uses by people are not limited or might potentially cause illness or disease. In the sections that follow, we will explore how different agencies have defined aquatic ecosystem health, and thus how they have selected measurement endpoints and set numeric and narrative criteria against which to judge the "health" of the system.

REVIEW OF APPROACHES FOR MONITORING AEH

3.0 REVIEW OF APPROACHES FOR MONITORING AEH

A variety of programs exist in Canada, for assessing the health of surface water environments, and those programs are triggered at municipal, provincial and federal levels. Here we review some examples of programs in Canada and internationally, with an attempt to illustrate a variety of approaches.

3.1 Canada

3.1.1 MMER/PPER

Federally, Environment Canada developed environmental effects monitoring (EEM, Environment Canada, 2004) regulations that require active mines and pulp mills to assess effluent-related effects on fish (sentinel fish populations), fish habitat (invertebrate community surveys) and the use of fisheries resources (fish tissue tainting and body burdens). Those EEM programs are "effects-based" in that effects on biological endpoints are used to trigger management decisions, while changes in water or sediment quality do not. Effluent-related variations in parameters such as growth, condition and mean age are interpreted as being important, as are large effluent-related variations in indices of benthic community composition. Where "large" effects are observed, subsequent studies are used to "confirm" the presence of effects, and the extent and magnitude of effects (Figure 1). Stakeholder consultation is recommended for determining when effects are too large in extent or magnitude.

In the development of these programs, Environment Canada did not provide a formal definition of a healthy aquatic ecosystem. The program rather is designed to determine whether "effects" (impacts) have been caused by point-source discharges. There are general suggestions on how large "effects" need to be before they should be considered large. Effects on indices of benthic community composition that exceed the normal range of variability observed in reference communities are considered evidence of large effects, and where the normal range is typically defined as the mean reference condition ± 2 standard deviations. Large effects on fish population endpoints are typically differences of 25% or more in endpoints like gonad size, liver size and growth, between reference and exposure populations.

In these programs, effluent, water and sediment samples are collected, and analyzed for a number of parameters. Water and sediment data alone are not used to declare the condition of sites, but are used to support conclusions based on biological endpoints. Effluent toxicity is also NOT used to declare the condition of a site, but rather is used as evidence that effluent may be the cause of observed biological effects.

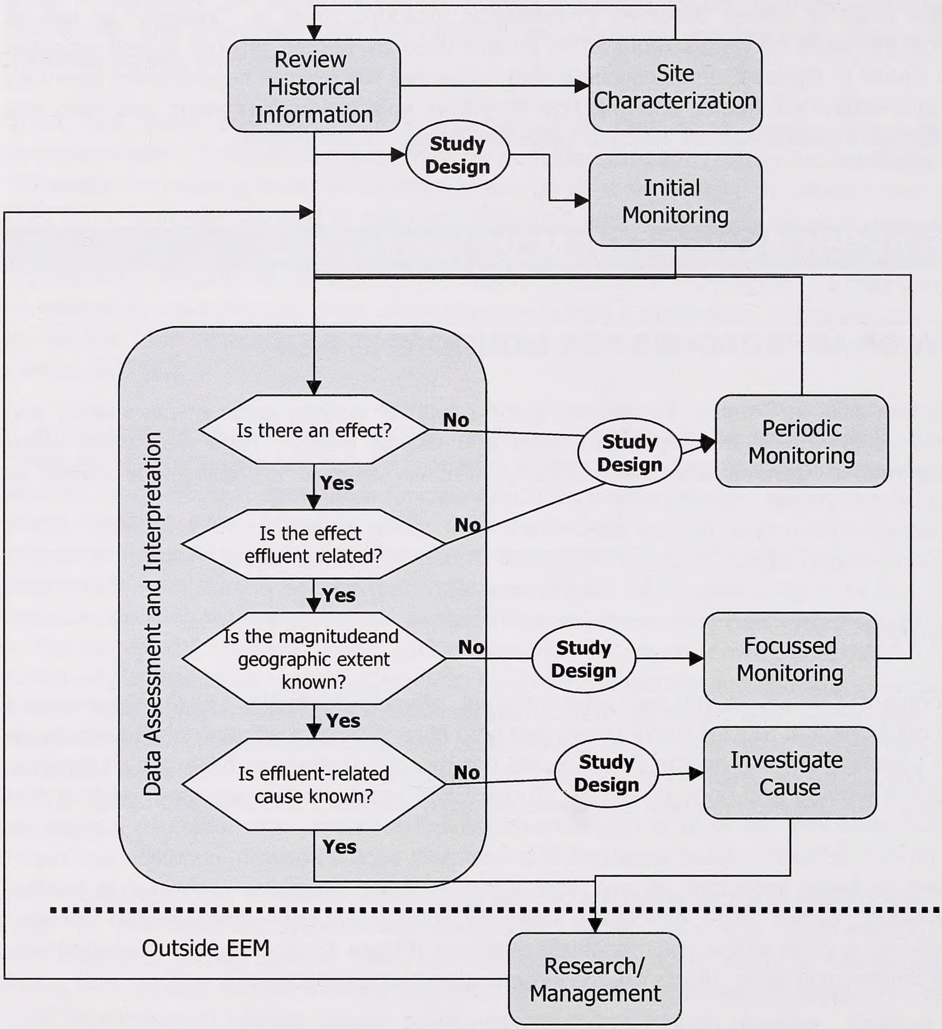


Figure 1. Generalized flow chart of activities for EEM studies in Canada. Redrawn from Environment Canada (2002).

Federal EEM manuals recommend a variety of study design approaches including the classic upstream-downstream, or control-impact designs (as per Green, 1979). More recently, the EEM guidance documents have begun to recommend the "Reference-Condition Approach" or RCA (Reynoldson et al., 1997) in which data are collected from regional reference locations considered to be somewhat similar (but not exact matches) to the site(s) being evaluated (Figure 2). Upstream (site-

specific) controls can be used to assist in evaluating the effects of point source discharges. The combined RCA with site-specific reference sites is the most informative design because it detects point-source impacts, and puts the observed effects in terms of the background variability (Figure 3).

Figure 2. Schematic of a watershed showing several regional reference and a single "impaired" site that would be judged relative to the reference sites. The site upstream of the "impaired" site could be used as a site-specific reference to control for upstream influences and test for effects associated with a specific point-source discharge (arrow).

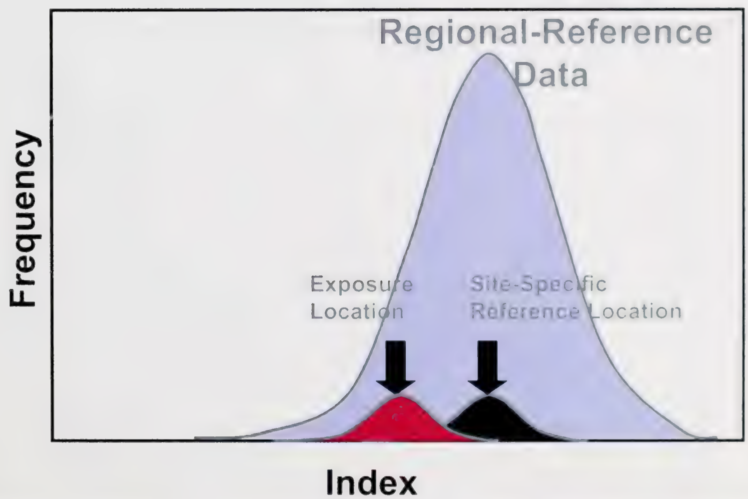


Figure 3. Schematic showing the potential relationship between regional-reference and site-specific reference data, and how an effect at an exposure location could be set within the context of regional-reference data.

3.1.2 Municipal Wastewater effluent (MWWE)

Environment Canada has recently developed an EEM approach for evaluating effects associated with municipal wastewater effluents (MWWE; Kilgour et al., 2005; Figure 4). In this framework end-of-pipe toxicity, and receiving environment chemistry are considered potential indicators of receiving-environment biological effects. Where a receiving environment is shown to have water or sediment chemistry that is considered to have poor quality when compared to water or sediment quality guidelines, the framework recommends confirming the presence of biological impacts by conducting biological studies. The exceedance of water and sediment quality guidelines is considered evidence of potential biological effects that need to be confirmed. Where complex effluents are discharged into a receiving environment, water and sediment quality guidelines may not protect the environment because there are guidelines only for select compounds and chemicals. Biological studies are, thus, considered the only definitive evidence that effects have or might occur.

The framework was founded on the philosophy that it is only biological impacts that are of ultimate concern. Where biological studies are unavailable, difficult or expensive to carry out, it is recognized that "screening-level" assessments will have to involve comparison of receiving environment chemistry against recognized guidelines.

This assessment framework assumes that a healthy aquatic environment is "functioning" and diverse. An unimpaired fish community was proposed as the ultimate indicator of a healthy system. Impacts on lower trophic levels are considered acceptable, so long as they in themselves do not forecast impending effects on the fish community. A loss of any abundant (common) fish species is considered unacceptable in this framework. Effects on sentinel fish population parameters and on indices of invertebrate community composition or algal or plant biomass are considered acceptable, so long as effects are within specified limits, and there are no temporal degrading trends.

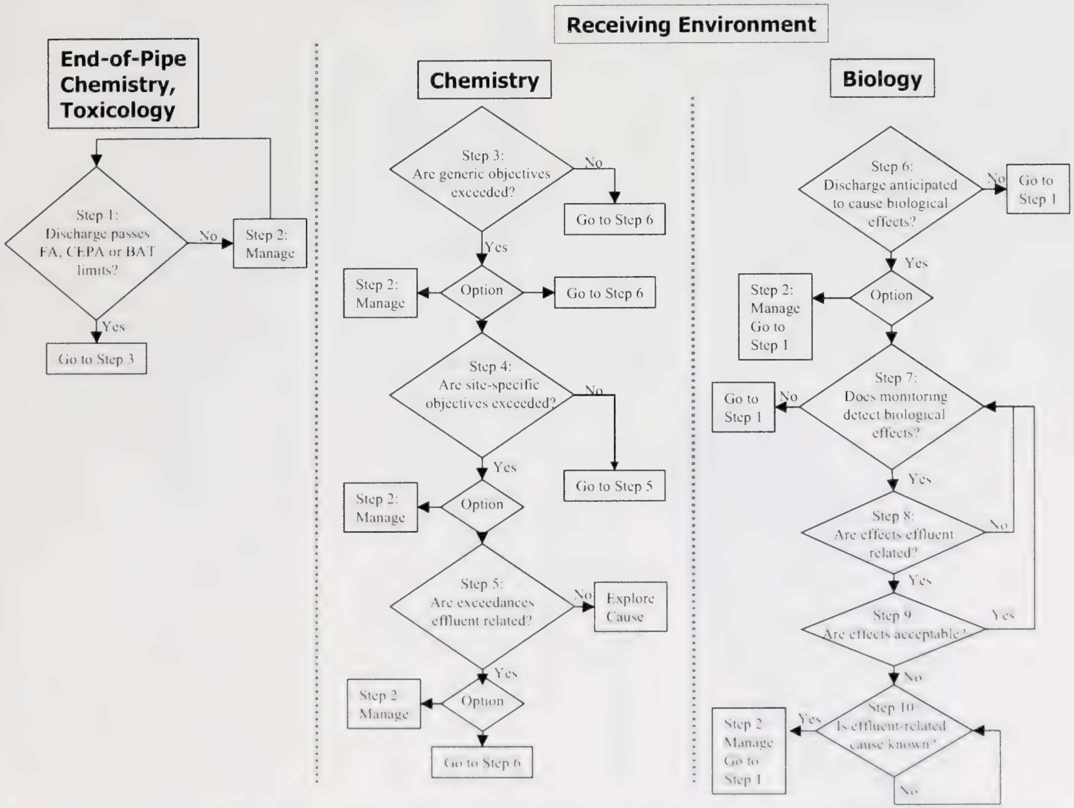


Figure 4. Detailed flow chart showing the sequence of events for carrying out assessments of effluent quality, and receiving-environment effects (from Kilgour et al., 2002).

3.1.3 EMAN

The Ecological Monitoring and Assessment Network (EMAN) is made up of linked organizations and individuals involved in ecological monitoring in Canada to better detect, describe, and report on ecosystem changes. The network is a cooperative partnership of federal, provincial and municipal governments, academic institutions, aboriginal communities and organizations, industry, environmental non-government organizations, volunteer community groups, elementary and secondary schools and other groups/individuals involved in ecological monitoring. EMAN links different groups, and makes recommendations about protocols that can be used to monitor ecosystem health. For aquatic environments, EMAN recommends protocols for monitoring benthic invertebrates, parasites in fishes, phytoplankton, zooplankton, and ice on/off conditions in lakes. The EMAN umbrella includes the CABIN network (below) and the Canadian Community Monitoring Network, both of which are community-based activities, driven by government.

3.1.4 CABIN

As part of Canada's need to effectively monitor the health of our fresh waters, the Canadian Aquatic Biomonitoring Network (CABIN) was developed by Trefor Reynoldson of the National Water Research Institute. This network promotes a common bioassessment approach and standardized sampling protocols. CABIN is intended to be a collaborative program developed and maintained by Environment Canada to establish a network of reference sites available to all users interested in assessing the biological health of fresh water in Canada. The CABIN protocols specify collection, laboratory processing and data interpretation for communities of benthic macroinvertebrates from "reference" sites. The CABIN manuals, based on research by Reynoldson et al. (2003, 2004) and others specify general definitions for reference sites, while the data interpretation approaches assist in identifying impaired aquatic environments (relative to reference).

There are a variety of ways to analyze RCA-style data. Reynoldson et al. (2003, 2004) describe one method which involves the following general procedures (Figure 5):

- clustering reference sites on the basis of benthic community assemblages;
- developing multivariate discriminant models that separate clusters of sites using non-effluent related habitat variables;
- use of habitat models to assign exposure sites to previous reference-site clusters;
- use of plotting and other statistical tools to determine whether indices of composition for exposure sites fall within expected bounds from reference sites.

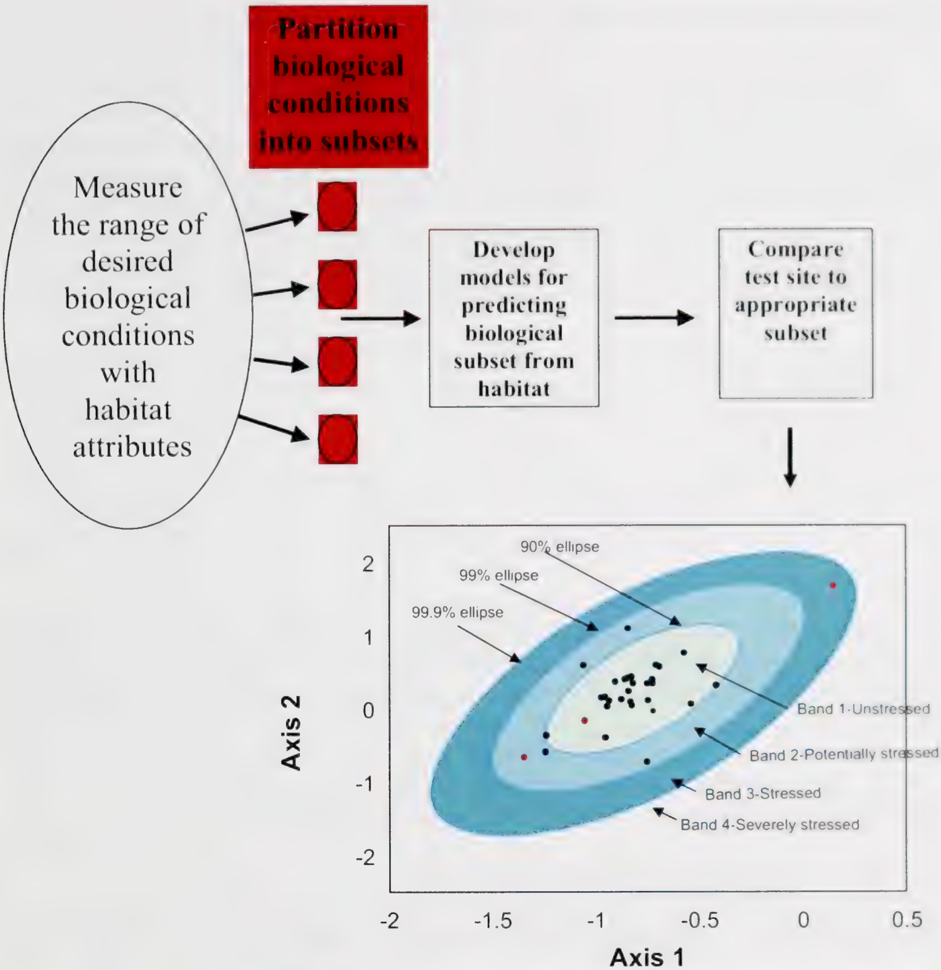


Figure 5. General approach to analysis of benthic invertebrate community data as specified by the CABIN protocols. From Reynoldson et al. (2003, 2004).

3.2 Provinces

3.2.1 Alberta

Four examples of monitoring programs/initiatives in Alberta are worth discussion. These include the Northern Rivers Basins Study/Northern Rivers Ecosystem Initiative (NRBS/NREI), the Instream Flow Needs (IFN) work in the South Saskatchewan River, the Strategic Overview of Riparian and Aquatic Condition (SORAC) recently completed by the province for the South Saskatchewan River basin, and the Regional Aquatic Monitoring Program (RAMP) carried out by oil sands developers in the Fort McMurray area.

3.2.1.1 Northern Rivers Basins Study - Northern Rivers Ecosystem Initiative

Most similar to the Initial Assessment of Aquatic Ecosystem Health that is about to be undertaken by Alberta Environment was the Northern Rivers Basin Study (NRBS) and the follow up Northern Rivers Ecosystem Initiative (NREI). The Northern River Basins Study (NRBS) was designed to address the ecological concerns about pulp mill expansion and to increase scientific knowledge about conditions in the Peace, Athabasca and Slave Rivers (NRBSB, 1996). The five-year study, jointly sponsored by the governments of Canada, Alberta and the Northwest Territories, was initiated in 1992. The study's objectives were to gather and interpret sound scientific information about the basins, develop appropriate recommendations for basin management, and communicate effectively with the public.

NRBS researchers proposed that the perception of "health" varies with each ecosystem and over time. NRBS scientists developed the framework, below, for monitoring and assessing aquatic ecosystem health.

Step 1: Identify ecosystem goals. In the first step, a group of stakeholders, armed with the best available scientific information, begin to describe what is desired. It was recommended that stakeholders include public representatives, special interest groups, industry and all levels of government.

Step 2: Develop specific management objectives. Once the goals are defined, they must be further refined into a specific management strategy. This general action plan describes what information is required to address the situation. Knowledge of current monitoring and regulatory requirements may influence the strategy.

Step 3: Select appropriate ecosystem indicators. In this step, specific measurable attributes are identified that provide information relevant to the specific management objectives.

Step 4: Monitor and assess the state of the chosen indicators.

Step 5: Take appropriate action. Manage issues, or refine the goals, objectives and/or indicators.

The Northern Rivers Ecosystem Initiative (NREI) was the Government of Canada, Government of Alberta and Government of Northwest Territories' response to the recommendations of the Northern River Basins Study. Through NREI, science teams focused on priorities such as pollution prevention, endocrine disruption in fish, drinking water and enhancing environmental effects monitoring. Studies continued into the incidence of fish abnormalities and the effects of land use, flow regulation and climate change on aquatic ecosystems. The five-year initiative, completed in 2003, was administered by a Steering Committee with representatives from Canada, Alberta and the Northwest Territories.

3.2.1.2 Instream Flow Needs (IFN) Study – South Saskatchewan River

Pursuant to Alberta's *Water Act*, a Framework for Water Management Planning was produced in 2001 (Alberta Environment 2001). The framework includes a Strategy for the Protection of the Aquatic Environment and promotes the establishment of Water Conservation Objectives that are defined as the amount and quality of water necessary for the:

- protection of a natural water body and its aquatic environment, in whole or in part;
- protection of tourism and recreation, and
- management of fish and wildlife.

The South Saskatchewan River Basin Water Management Plan (SSRB WMP) is reviewing water management including irrigation expansion guidelines that were developed in 1991. As input to the SSRB WMP, an Instream Flow Needs Technical Team was appointed to calculate the instream flow needs (IFN) of the South Saskatchewan River system. That team (Clipperton et al., 2003) determined the instream flows required to protect fish resources, fluvial processes, water quality and riparian habitats.

The approach taken by the study team acknowledges that fish, wildlife, and riparian vegetation communities evolved and adapted to the fluvial processes and habitat characteristics of the pre-disturbance rivers within the South Saskatchewan River Basin. Protecting, maintaining or restoring the aquatic ecosystem must be founded on rehabilitating and managing fluvial processes that create and maintain habitat vital to fish, wildlife, and riparian species.

3.2.1.3 SORAC

In July 2002, Alberta Environment (AENV) commissioned Golder Associates Ltd. (Golder) to conduct a qualitative "Strategic Overview of Riparian and Aquatic Condition" (SORAC) of the mainstem rivers of the South Saskatchewan River Basin (SSRB) in southern Alberta (Golder, 2003; http://www3.gov.ab.ca/env/ water/regions/srb/pdf_phase2/SORAC_Report_complete.pdf). The purpose of this initiative was to derive a sense of the integrity of the aquatic ecosystem. The project was an assessment based solely on the opinions of a 'Best Judgment Panel' (BJP) and did not involve a review of any quantitative data or previously undertaken analyses. The panel was selected by AENV staff to reflect the diverse fields of expertise that must be taken into account in any ecosystem assessment.

The SORAC report relates to the mainstem rivers, associated riparian zones and wetlands, and watershed upland ecosystems of the South Saskatchewan River Basin (SSRB) in Alberta. The objectives of the investigation were to:

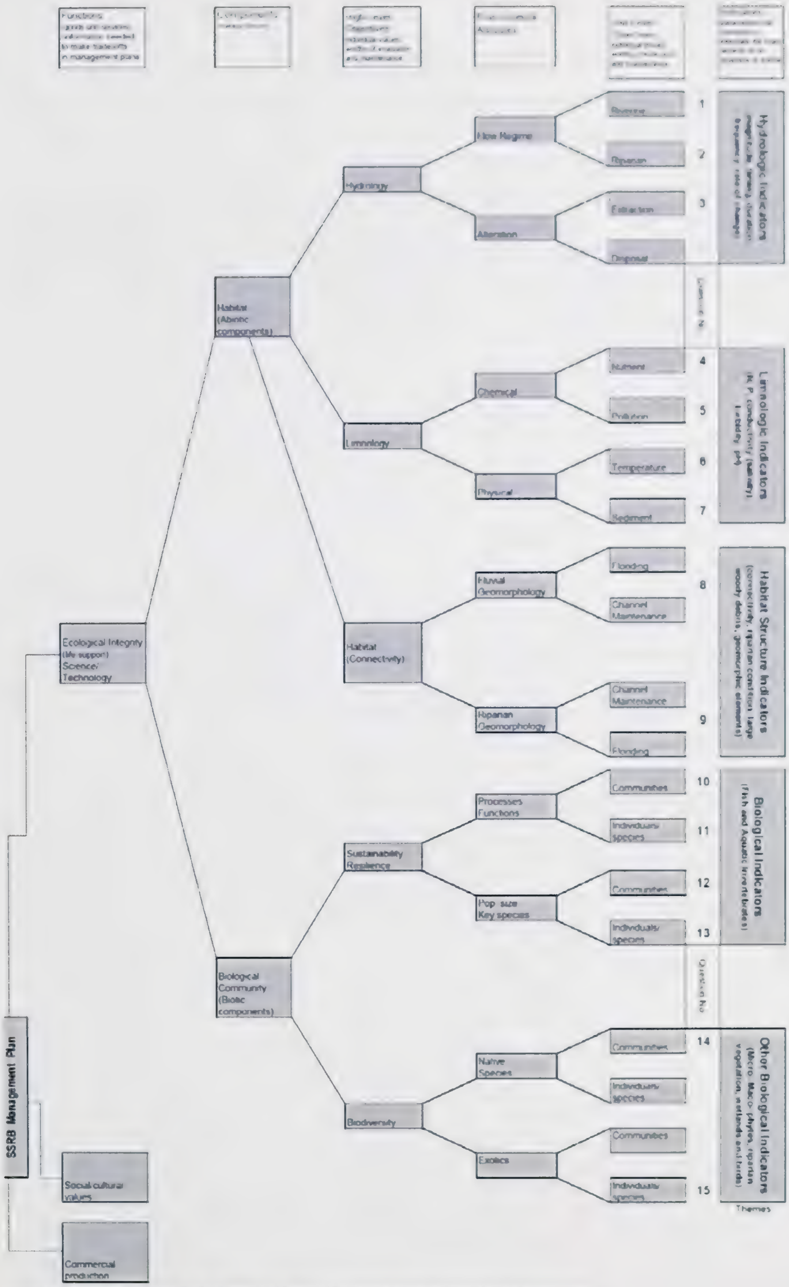
- record the current BJP views of the environmental conditions and any associated trends of the SSRB on a reach basis;
- identify the key issues leading to the ecological assessment by sub-basin and by reach;
- identify the key analytical techniques and data necessary to enable such an assessment to be made quantitative and defensible;
- identify knowledge and/or data gaps; and
- recommend future research and development directions.

The SORAC assessment design was based on qualitatively scoring professionals' interpretations of the condition of specific indicators (Figure 6) of the South Saskatchewan aquatic ecosystem. The grading system, numerically scored 0 to -3, indicated whether the panel considered conditions in a reach to be:

- *Unchanged/Recovered* (0) – most factors have either remained relatively unchanged over time or recovered from any disturbance;
- *Moderately Impacted* (-1) – most factors have changed measurably over time and some are near or approaching ecologically unacceptable values;
- *Heavily Impacted* (-2) – many factors have degraded over time and are below or forecasted to be below ecologically acceptable values; and
- *Degraded* (-3) – most factors are now below ecologically acceptable values.

These four grades coupled with a trend (improving, stable, or declining) provided an indication of the ecological status of the reach relative to an individual question. Each question represented a low-level objective which was an individual target or goal that a management plan could be aiming to protect (*e.g.*, a native species such as bull trout or a group of species that serve as indicators that the ecosystem has not been seriously altered).

Qualitative scoring by professionals was adopted in this analysis because there was a significant time constraint that precluded detailed analysis of existing biophysical data. Golder (2003) made several recommendations for improving assessments of the South Saskatchewan River including the development of quantitative data sets characterizing specific indicators of aquatic conditions (benthic invertebrates, spawning redds). It was generally expressed that quantitative analyses of health would be more defensible.



- numbers in the second column from the right refer to the questions used in the workshops
- low level objectives of this framework were used as a guide to the distribution of the 15 questions across the major themes

Figure 6. SOREC framework for organizing environmental indicators, and questions relating to the health of the South Saskatchewan River posed to professional panel

3.2.1.4 Regional Aquatic Monitoring Program (RAMP)

The RAMP (http://www.ramp-alberta.org/) is a cooperative effort funded by several oil sands developers to jointly monitor the Athabasca River downstream of Fort McMurray, and its tributaries, in support of their various Certificates of Approval to operate. RAMP components include fish communities, sentinel fish populations (sculpins), benthic macroinvertebrate communities, water and sediment quality, contaminant levels in fish tissues, and climate and hydrology. Sampling within RAMP is typically at a reach scale, defined as a relatively homogeneous section of river, often 2 to 5 km in length. The design of the benthic invertebrate community survey (Figure 7) includes both upstream reaches that act as site-specific controls, as well as regional reaches that help to put observed effects into a context. With 15 replicate benthic samples per reach in each year before (5 years) and after an oil sands project is developed, the RAMP benthic sampling designs have very high power to detect changes in time trends between upstream and downstream reaches (Hatfield et al., 2005). The regional-reference reaches have been very helpful in demonstrating the “insignificance” of effects. Regional reference sites are also used to establish normal operating ranges for water quality parameters in the RAMP study area.

3.2.1.5 Oldman River Basin Water Quality Initiative

The Oldman River Basin Water Quality Initiative (http://www.oldmanbasin.org/ orbwqi/) was formed in 1997 in response to serious concerns expressed in the community about protecting water quality in the Oldman River Basin. The Initiative's 1998-2002 Action Plan (April 1, 1998-March 31, 2003) emphasized the importance of three types of activities to be carried out during that five-year period: collecting baseline information on water quality (bacteria, nutrients, pesticides) and how to improve it, classifying land use, and communicating the activities of the Initiative.

During the first four years of the Initiative's activities, efforts focused on collecting data (water quality and land use), interpreting and analyzing it (exploring land use and water quality relationships at a Basin scale), and pursuing work on beneficial management practices (with, until recently, an agricultural emphasis).

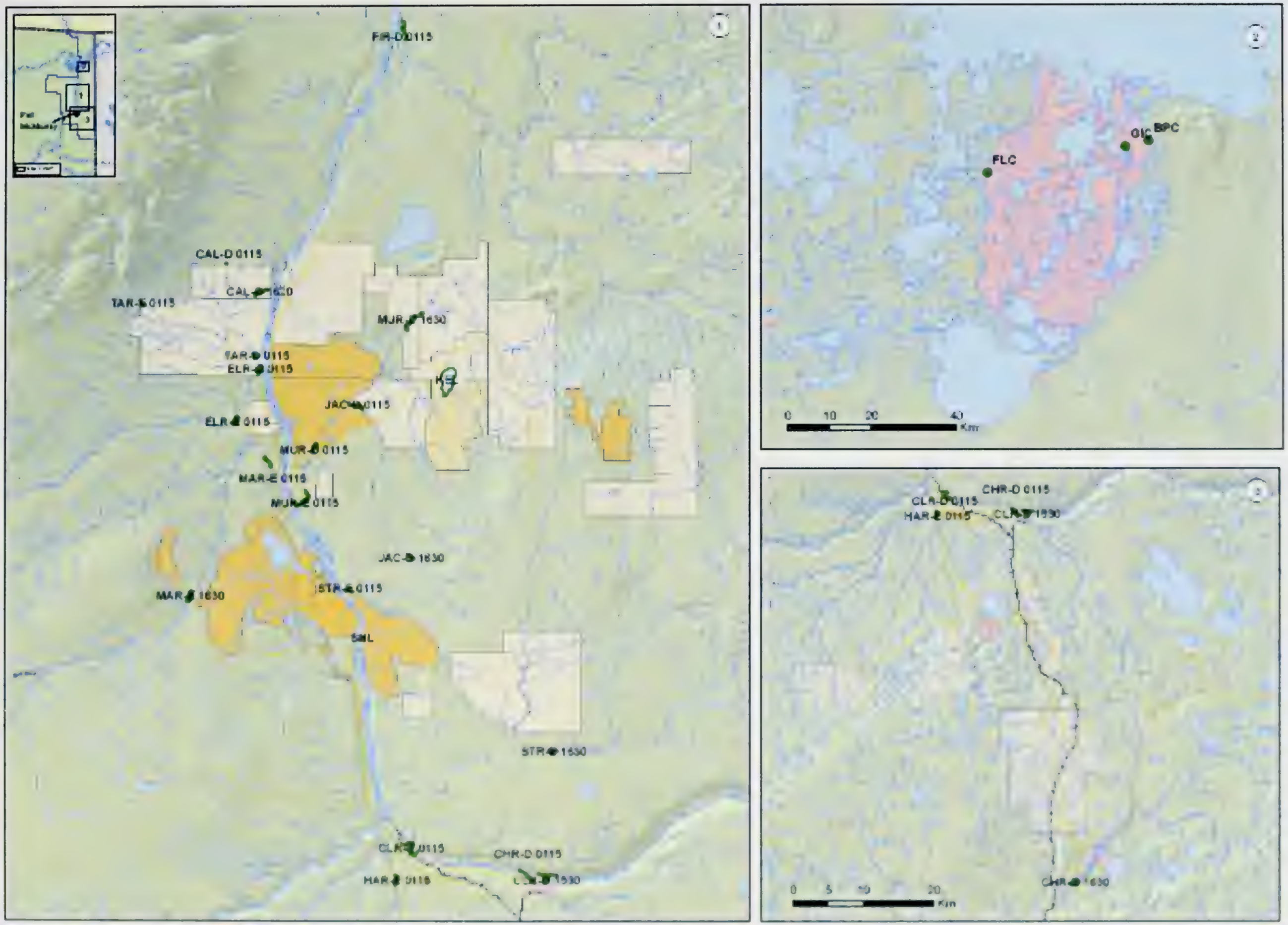


Figure 7. Map of the RAMP study area showing benthic sampling reaches in 2004 (green highlights). From Hatfield et al. 2005.

3.2.1.6 Bow River Basin Council

The Bow River Basin Council (http://www.brbc.ab.ca/) is a multi-stakeholder, charitable organization dedicated to conducting activities for the improvement and protection of the waters of the Bow River Basin. The Council was established in 1992 as an advisory body to the provincial Minister of Environmental Protection. Its broad mandate is to promote awareness, improvement and protection of Bow River water quality, foster cooperation among agencies with water quality responsibilities, and provide communication links among governments, interest groups and the general public. The Council includes representatives from urban and rural municipalities; irrigated and dryland agriculture; recreational, industrial and other interests; and first nations peoples within the Bow River Basin.

3.2.1.7 Alberta Biodiversity Monitoring Program

The Alberta Biodiversity Monitoring Program (ABMP; http://www.abmp.arc.ab.ca/) is designed to track changes in biodiversity and habitat elements over time and space across the province of Alberta. The ABMP samples terrestrial and aquatic habitats and biota, and landscape-scale elements. When fully implemented, the ABMP will sample terrestrial elements at approximately 1650 points distributed across Alberta on a 20 x 20 km grid. Aquatic elements will be sampled at two scales: larger entities (lakes and rivers) will be sampled at a provincial scale (100 sites across the province), while smaller aquatic habitats (streams, wetlands) will be sampled at an intensity similar to that for terrestrial elements. Each point will be sampled once every five years on a rotational basis.

Initially, ABMP aquatic protocols were designed to sample basin characteristics, water physiochemistry, benthic macroinvertebrates, zooplankton, phytoplankton and benthic algae, amphibians, and fish for standing and flowing water. The originally selected protocols are under revision, because they were not considered appropriate for the aquatic sites actually encountered during initial field tests. Eaton (2004) is currently identifying appropriate field-sampling protocols for use in Alberta. The ABMP is going to compare changes in biodiversity over time and space at a regional scale (approximately 40 sampling sites) to evaluate whether conditions are degrading or improving.

Figure 8. Location of long-term monitoring lakes sampled by Alberta Environment and partners.

The overall statistical goals of the ABMP are to:

(1) detect a change of 3% per year in select parameters within a region after 15 years of surveys (three full sampling rotations) with a 90% certainty. The selected parameters include (a) species richness of targeted groups, (b) population density of select species, (c) physical / structural habitat characteristics.
(2) detect a difference of 50% in the select parameters between regions after five years of surveys (one complete sampling rotation) with a 90% certainty.
(3) have a <10% probability of declaring a difference in these parameters when one does not exist.

3.2.1.8 Alberta Agriculture, Food and Rural Development (AAFRD)

Alberta Agriculture, Food and Rural Development (AAFRD) conducts a variety of surface and groundwater monitoring programs, and conducts specific research studies focused on sources (e.g., manure, land use practices) of surface water quality problems. AAFRD is leading the Alberta Environmentally Sustainable Agriculture (AESA) program which along with partners including Alberta Health and Wellness, and Agriculture and Agri-Food Canada (PFRA). The objective of the AESA is to describe trends in water quality resulting from agricultural non-point sources on a province-wide scale. Monitoring is being conducted in 23 watersheds across the central and southern parts of the province (Figure 9). Water quality is judged relative to provincial water quality guidelines.

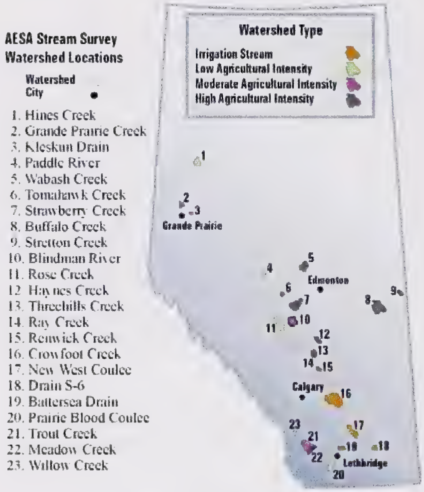


Figure 9. Map of Alberta showing watersheds being monitored by the AESA program.

3.2.1.9 Cumulative Environmental Management Association (CEMA)

The Cumulative Effects Management Association (CEMA), a multi-stakeholder group made up of industry, government, non-government organizations and First Nations. The CEMA mandate is the assessment and management of cumulative environmental impacts of oil sands development in the Wood Buffalo region of Northeastern Alberta. Government agencies consider CEMA recommendations and implement where necessary. CEMA has five working groups, including the Sustainable Ecosystems, and Surface Water groups. The sustainable ecosystems group includes fish and wildlife, and biodiversity as key ecosystem components, while the surface water group is developing surface water quality objectives for the Lower Athabasca River, a management framework for the Muskeg River system and instream flow needs for the Lower Athabasca River.

3.2.1.10 Alberta Environment

Alberta Environment conducts extensive water quality field studies throughout Alberta to support the government's regulatory, water management and environmental assessment decision-making. The department also provides significant consultative and advisory services, on a wide range of water quality issues, to various agencies, industries, institutions and municipalities.

Field investigations of water quality are classified into four functional activities, depending on the nature of the issue being addressed. Long-term monitoring, includes ongoing studies at fixed locations that provide data for the analysis of trends in water quality over time. Short-term surveys, includes studies that provide data to describe water quality patterns across defined geographical areas. Impact assessments are studies conducted to evaluate the impact of a specific facility or activity on water quality. Research is also conducted to test hypotheses about factors influencing water quality.

Alberta Environment is involved in a number of partnerships (http://www3.gov.ab.ca/env/water/SWQ/partners.cfm) that facilitate the agencies' ability to quantify and report on the state of surface waters in the province (Figure 10). At the provincial level, AENV is members of AESA, CEMA, NREI and RAMP. AENV also participates on the Prairie Provinces Water Board, the Mackenzie River Basin Transboundary Agreement. The agency is active in monitoring lakes and rivers across the province.

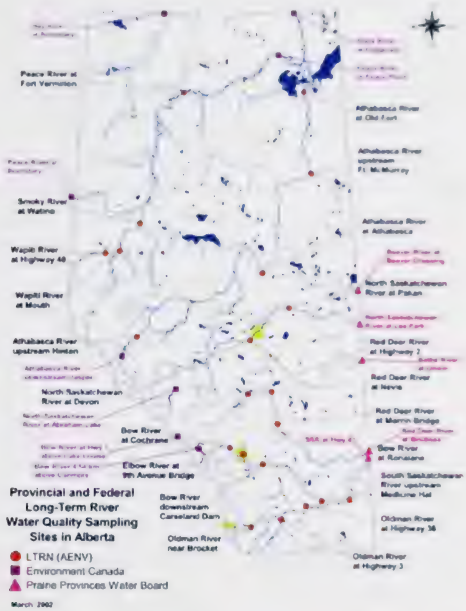


Figure 10. Active monitoring locations held by Alberta Environment or partners.

3.2.2 Ontario

A variety of approaches are evolving separately in Ontario. The province has two Ministries (Environment, Natural Resources) that have jurisdiction over water-related resources. The Ministry of the Environment (MOE) has jurisdiction over water quality and quantity, while Natural Resources (MNR) has jurisdiction over fisheries. Neither Ministry has an overarching philosophical view on how to evaluate aquatic ecosystem health. MOE has recently assigned resources to the development of a province-wide benthic invertebrate monitoring network (Ontario Benthic Biomonitoring Network, OBBN), based on collection and reporting by volunteer organizations. The long-term goal of the OBBN is to warehouse data, and provide a web portal that can provide access to data.

MOE also maintains its Provincial Water Quality Monitoring Network (PWQMN) of river sites at which it conducts routine (normally once monthly) sampling and analysis of water quality parameters. Parameter lists vary by site depending on local conditions, and knowledge of potential issues. There is no formal linkage at the present time between the OBBN and the PWQMN, though they are both driven by the same management team.

MNR has been developing the Ontario Stream Assessment Protocol (OSAP) which provides methodologies for collecting fish communities, benthic invertebrate communities, in-stream physical habitats, temperature and water levels. With the exception of the fish community survey, all methods are appropriate for volunteer organizations. A database (HABPROGS) is used to warehouse and summarize data. Staff from a number of Conservation Authorities are trained annually on the protocols, and they submit data to a data keeper on a voluntary basis. There is no formal mechanism to keep this specific program operating, and reporting out on a province wide basis has not been formally supported.

Kilgour and Stanfield (2005) recently conducted an analysis of fish and benthic communities in the Toronto area, and developed an approach to estimating the historical reference condition based on hindcasting along a gradient of urbanization. In that analysis, percent impervious area was used as an indicator of human development in urban areas. Relationships between indices of fish and benthic community composition were developed (Figure 11) and have been used to estimate the degree of impairment in Toronto-area streams with respect to fish, benthos, surface water temperatures, and in-stream habitat features like mean width, and width:depth ratio. This sort of analysis was proposed because the Toronto area has few (if any) reference areas on which to characterize a reference condition.

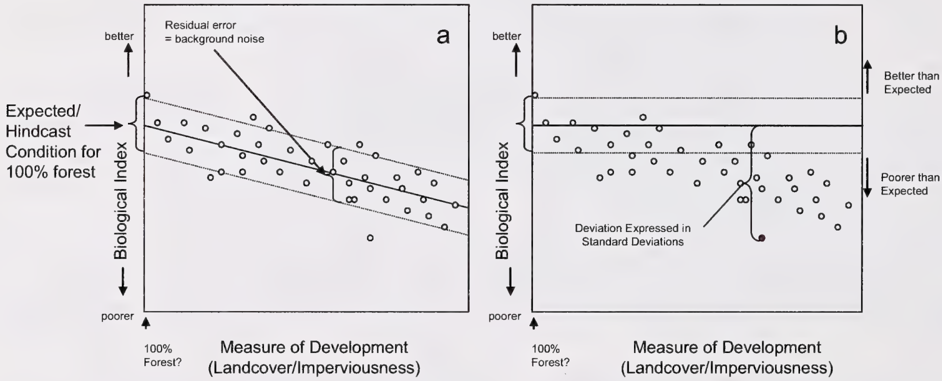


Figure 11. Conceptual figure illustrating the hindcasting modeling approach (a), and how the biophysical condition of sites is assessed relative to a hindcast or predicted historical condition (b). Based on the model (a), the expected range of values is the range of values shown at 100% forest cover. Deviations from the expected condition (b) are expressed in standard deviations. From Kilgour and Stanfield (2005).

3.2.3 Manitoba

The Manitoba Water Stewardship agency (http://www.gov.mb.ca/ waterstewardship/ index.html) conducts a number of functions in the protection and enhancement of water resources in that province. The Water Quality Management Section conducts monitoring, carries out special studies, and revises water quality objectives. Monitoring involves measurement of surface water chemistry, and the characterization of communities of benthic macroinvertebrates. The Water Stewardship agency is also very active in monitoring water levels in lakes and rivers, and provides flood forecasts.

Manitoba Conservation is engaged in a number of activities, of which two pertain to aquatic systems (dragonfly monitoring program, amphibian monitoring program). Information on rare species is warehoused with the Conservation Data Centre (http://web2.gov.mb.ca/conservation/cdc/). The CDC has linkages with national and international databases. Occurrences of rare species are assembled into a GIS database that can be queried.

3.3 Municipalities

Conservation Authorities in the Toronto area present good examples of municipal agencies actively participating in aquatic environment monitoring and assessment activities. Credit Valley Conservation (CVC), in particular, has developed an over-arching framework for its watershed monitoring and assessment work (http://www.creditvalleycons.com/state/). There, CVC has declared the fish community the ultimate indicator of ecological health and routine monitors fish assemblages in tributary streams. Benthic invertebrates are used as an early-warning indicator, while water quality (conventional pollutants, nutrients, metals, persistent organics, pesticides), hydrological and fluvial geomorphological parameters are also monitored. CVC assigns sites into two tiers (1 and 2). Tier 1 sites are monitored annually and will be used to track long-term trends in aquatic environmental condition. Tier 2 sites are identified on an as-needed basis, and are typically used to evaluate point-source discharges, or specific land use activities.

Toronto and Region Conservation Authority (TRCA) similarly has a rigorous aquatic environment monitoring program in which fish, invertebrates, periphyton and water quality are monitored at numerous sites every year. The Authority has a suite of some 300+ sites at which monitoring activities are carried out on a rotating three-year basis (100 or so per year). The Authority publishes an annual "report card" that updates conditions within specific watersheds. Research studies are carried out on a site-specific basis to address local issues, normally driven by development pressures (http://www.trca.on.ca/water_protection/ monitoring/default.asp?load=network).

3.4 International

3.4.1 Australia

Through the National River Health Program (http://www.deh.gov.au/water/ rivers/nrhp/), the first Australia-wide assessment of the health of Australia's diverse and unique aquatic systems has been undertaken at approximately 6000 sites across Australia. The assessment was established as a partnership between river management agencies across Australia, the Australian Government, researchers and communities.

The principal means of assessing the "health" of rivers in Australia is through standardized inventories of benthic macroinvertebrates. Sites have been selected with advice from state agencies, local governments, industry, catchment organisations and communities, having regard to key river and catchment management issues. The benthic community sampling and analysis protocol (AusRivAS) consists of a series of state-specific mathematical models which use field data to predict the aquatic macroinvertebrate families that would be expected to be present in surveyed river sites in a "reference" (that is, pristine or near pristine) condition. These models have been developed using habitat

information and macroinvertebrate surveys at approximately 1500 carefully selected reference sites that are in relatively pristine or the best possible condition.

River health assessment is based on the differences between what is found at test sites and what was predicted to have occurred there from a set of reference sites with similar geographic, physical, and chemical features.

The Australian Government is investing in new tools for quantifying chemical and physical condition of riverine habitats, as well as diatoms, fish, and benthic respiration (http://www.deh.gov.au/water/rivers/monitoring.html).

The Environmental Flows Initiative (http://www.deh.gov.au/water/rivers/ flows.html#efi) was initiated to address perceived gaps in knowledge considered necessary for the management of instream flows. Moneys are being spent on research into methods for modeling flows in arid environments, and for understanding the relationships between flows and the standing stocks of aquatic plants and animals.

3.4.2 South Africa

Similar to the efforts in Australia, South Africa has implemented a River Health Program (http://www.csir.co.za/rhp/rhp_background.html) which is responsible for characterizing the ecological condition of river systems. The general methodology employs a reference-condition approach in which data from minimally impaired reference sites are used to develop an expected condition against which "test" sites are judged. Benthic macroinvertebrates are the principal ecological indicator in the program, with stream physical and chemical properties used as supporting environmental information (Dallas, 2000).

3.4.3 European Environment Agency

The European Environment Agency requires that member countries endeavour to meet minimum environmental standards. Member countries classify the health of river systems using a variety of indicators, but most use water chemistry, and several use benthic macroinvertebrates (http://themes.eea.eu.int/Specific_media/water/indicators/WEC04e%2C2003.1013/36_River_ Classification_final.pdf).

The European Union has recently mandated each of its 15 member countries to develop aquatic environment monitoring programs, and to develop programs that improve water quality to high levels, except for those systems designated degradable for human uses. The core components of the biomonitoring programs are to be periphyton and plants, benthic macroinvertebrates and fish.

3.4.4 Environment Agency – UK

The Environment Agency in the UK is active in quantifying the quality of surface waters in rivers using biological, chemical and aesthetic indicators. The program in the UK is extensive, with over 7,000 actively monitored sites. The map below (Figure 12) illustrates surface water quality trends in the UK based on surveys of benthic macroinvertebrates. The UK classification scheme for invertebrates is based on the River Invertebrate Prediction and Classification Scheme (RIVPACS). RIVPACS requires

samples from "least-impaired" reference locations on which multivariate models of composition are derived. The models for reference sites are used to predict the kinds of benthic fauna that should be expected at sites of "unknown" quality (http://www.dorset.ceh.ac.uk/River_Ecology/River_Communities/Rivpacs_2003/rivpacs_introduction.htm), in much the same way as in the "reference-condition approach" described in the CABIN program above.

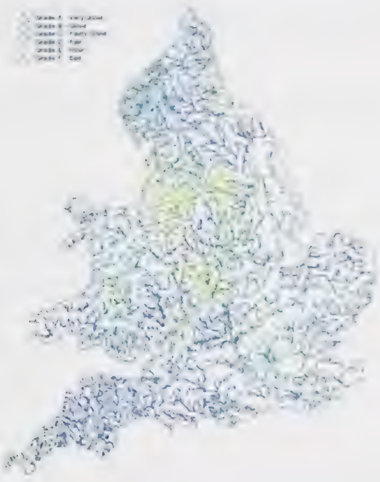


Figure 12. Map of the UK illustrating trends in surface water quality based on communities of benthic macroinvertebrates.

3.4.5 United States

3.4.5.1 Upper Mississippi River System

THE USGS (1998) compiled a science-based assessment of the health of the Upper Mississippi River system (http://www.umesc.usgs.gov/reports_publications/status_and_trends.html). From a scientific perspective the USGS (1998) considered river health to include:

- River form and condition;
- Connectivity between the main channel and its floodplain;
- Annual flood pulse, channel-forming floods, and infrequent droughts; and
- Fauna.

In its assessment of the Upper Mississippi, the USGS focused on hydrology, water and sediment quality, submersed aquatic vegetation, floodplain forests, benthic macroinvertebrates, mussels, fish and birds. In all cases, simple indices of condition (e.g., numbers per m^2 of key indicator species like fingernail clams) are tracked over time within specified reaches. Time trends are used to identify areas of continued degradation or improvement.

3.4.5.2 Ohio

Ohio is included here as an example of what occurs in the US because aquatic environmental monitoring is very thorough in that State. There, regional-reference locations are used to develop the anticipated "least-impaired" condition for inventories of benthic invertebrate communities, and are what test locations are judged against (Yoder and Rankin, 1995; Yoder and Smith, 1999). Where "test" locations are shown to be similar to the reference condition, the aquatic environment is considered to be in good condition. Where test locations are shown to differ from the reference condition, additional studies are conducted to determine the contribution of specific discharges to the impaired status.

3.4.5.3 Environmental Monitoring and Assessment Program (EMAP; U. S. Environmental Protection Agency)

The Environmental Monitoring and Assessment Program (EMAP) is a long-term research initiative by the U.S. Environmental Protection Agency (EPA, http://www.epa.gov/emap/index.html). EMAP began in the late 1980's and underwent more than a decade of protocol development, testing, and regional demonstration projects. The main goals of EMAP are to (1) develop the science for a state-based statistical monitoring framework to determine condition, and detect trends in condition, for all of the U.S.'s aquatic ecosystems; (2) transfer this technology to states, tribes, and regions, and (3) have the EMAP approach implemented by states, tribes, and regions. The EMAP sampling design provides unbiased, representative monitoring of aquatic resources with a known confidence level.

EMAP uses indicators to assess the condition of ecological resources being monitored. Indicators include vertebrates (fish, amphibians, riparian birds), invertebrates (benthic macroinvertebrates, zooplankton, zebra mussels), algae (sediment diatoms, chlorophyll a, stream periphyton), microbes, water characteristics (temperature, dissolved oxygen, pH, nutrients, Secchi depth), hydrological and substrate conditions, riparian vegetation, large woody debris, toxic chemicals (fish tissue contaminants, sediment toxicity), climate, elevation, land use, human population density, channel or flow modification, catchment area, water body size, and channel slope. Ecological condition at a specific site is compared to similar sites (benchmark sites) that are thought to be in a relatively pristine state to determine if the study site is ecologically impaired.

3.4.6 Summary

Few of the agencies that carry out aquatic environmental monitoring have made the effort to declare what they consider to be a healthy ecosystem, that is to define "aquatic ecosystem health". The "condition" of biological indicators (typically benthic invertebrates and fish), however, invariably is judged relative to what is observed in reference locations, and those reference locations (areas, sites) are invariably either upstream, adjacent, or at least close by (within the same watershed or ecoregion). A variety of approaches have been developed to quantify the deviation of biological responses from reference conditions, but those differences are essentially subtly different approaches to the development of statistical models. There is no complete agreement on how large biological effects need to be before an aquatic environment is considered "unhealthy". Systems are definitely in poor condition when there is no life, or when biological measurements fall outside the normal range of values (however defined) observed in reference areas. Some consider "any" effect (no matter how small) to be an indication of significant impairment, but there is no consensus. New research into resilience and how much change a system can tolerate before changes are irreversible may be opportunities for

revising criteria in the future (e.g., Vinebrook et al., 2004), but considerable work remains to be done in that regard before the concept can be incorporated into criteria.

Physical indicators of aquatic environments are monitored by some agencies, but with considerably less consistency in methodologies than for biological measures. Further, declaring a site to be unhealthy based on physical measurements requires a certain understanding of the relationship between the physical measurements and some key biological indicators (see Clipperton et al., 2003). Those relationships are not always apparent, so using physical measures to interpret the health of an aquatic environment can be challenging.

Chemical indicators of aquatic environments are monitored by most agencies, especially water quality measures. Sediment quality is not monitored by as many agencies. Chemical quality guidelines developed by federal, provincial or state agencies are typically used to judge the condition of waterways. Guidelines are typically developed on the basis of laboratory exposures of single species to single chemicals. Often the lowest concentration causing mortality or reduction in growth of an aquatic plant or animal is divided by a safety factor to arrive at a chemical concentration (guideline) that is presumed to be protective of a large fraction of aquatic organisms.

Sediment quality guidelines are derived in a different way, often involving analysis of data from field studies of sediment chemistry and benthic communities. The highest chemical concentrations in sediments that co-occur with unimpaired benthic communities are often used as the guideline above which sediments could be considered potentially impaired.

Exceedance of a water or sediment quality guideline implies a potential for effects on biological endpoints, but is no guarantee. From a screening-level perspective, any exceedance of a guideline should trigger follow-up studies to explore potential biological effects. Further, guidelines have not been developed for every chemical released into aquatic environments. The absence of chemical exceedances, therefore, cannot be used as evidence that there are no biological effects.

Water and sediment quality may also naturally exceed published water or sediment quality objectives. In those cases, the use of natural background concentrations as observed in reference locations (as per biological studies) is an alternative way to evaluate the chemistry of surface water or sediments.

4.0 PROPOSED APPROACH TO ASSESSING ECOSYSTEM HEALTH IN ALBERTA

A generic schematic of a general approach to assessing aquatic ecosystem is health is presented in Figure 13 below. That scheme is briefly overviewed to illustrate how it can be used in the initial assessment. The work requirements within each task are then detailed to develop the scope of work for the Initial Assessment of Aquatic Ecosystem Health. In the scope of work that is described below, recommendations are made on the kinds of data that should be used as part of the initial assessment, and the nature in which those data should be summarized to carry out the assessment.

Step 1 is the development of a definition for a healthy aquatic ecosystem is in order to provide justification for the attributes that will be used in the assessment (i.e., selection of ultimate indicators). For the purposes of the Initial Assessment, it is recommended that the "pragmatic" approach of Calow (1995) be adopted. That is, the definition of a healthy system must recognize regional differences in stakeholder expectations, and that scientific interpretations of "health" are and will continue to evolve over time. Generally, and as in Section 2.0, healthy systems will be considered here as those in which the attributes (measurable endpoints) fall within acceptable limits, and where the limits are numeric or narrative criteria established on the basis of values derived from science (as per water and sediment quality objectives), or as observed in minimally degraded (or acceptable) reference locations. Where data from reference locations are used to set acceptable limits, natural spatial, seasonal, and annual variations should be considered. Limits may also be specified according to the human uses of the system.

Step 2 is normally a consultation phase that garners input on local issues of importance to stakeholders. Step 2 is desirable because (as above) the concept of health will vary with local uses, but managers and scientists should lead those discussions and provide guiding input.

For this *Water for Life* project, a general approach to assessing and defining AEH was developed during a one-day workshop (February 9, 2005) (Section 4.2). Based on the definition developed by the group (below), specific recommendations can be made as to the kinds of data that should be used as part of the initial assessment, and the nature in which those data should be summarized to carry out the assessment. The consultation step was not overlooked, but is not feasible given this initial assessment. The consultation process should be considered for any long-term assessments of aquatic ecosystem health.

Step 3 is the development of a framework for organizing potential indicators of aquatic environmental health and is required in order to clearly articulate why specific indicators are monitored and to articulate the management implications of specific conditions that might be observed in the environment (e.g., Cairns et al., 1993). During a workshop of AENV and JW project team members, as well as outside experts (Feb 9, 2005), the organizational charts in Figure 14, Figure 15 and Figure 16 were

developed. In general, there was agreement that healthy aquatic ecosystems had unimpaired human uses (Goal 1) and were functioning and diverse (Goal 2). When human uses of an aquatic environment are unimpaired the water is generally "drinkable", "swimmable" and "fishable". Drinkable and swimmable waters are not objectives under the Aquatic Ecosystem Health component of the *Water for Life* project. However, fishable environments are considered to be an important objective within the aquatic ecosystem health disciplines. "Fishable" populations of fish are fish that are desirable to consume because they do not have off-flavours or off-odours, have low concentrations of persistent, bioaccumulative chemicals and thus do not impose health risks to people and other animals, and that are abundant enough to collect for sport or commercial purposes.

The Goal of a Functioning and Diverse Aquatic Ecosystem has the following objectives:

1. Healthy biological communities;
2. Adequate chemical environment to support (1); and
3. Adequate physical environment to support (1).

Based on these objectives, measurable indicators and the criteria against which to judge condition, can be identified (Figure 16)

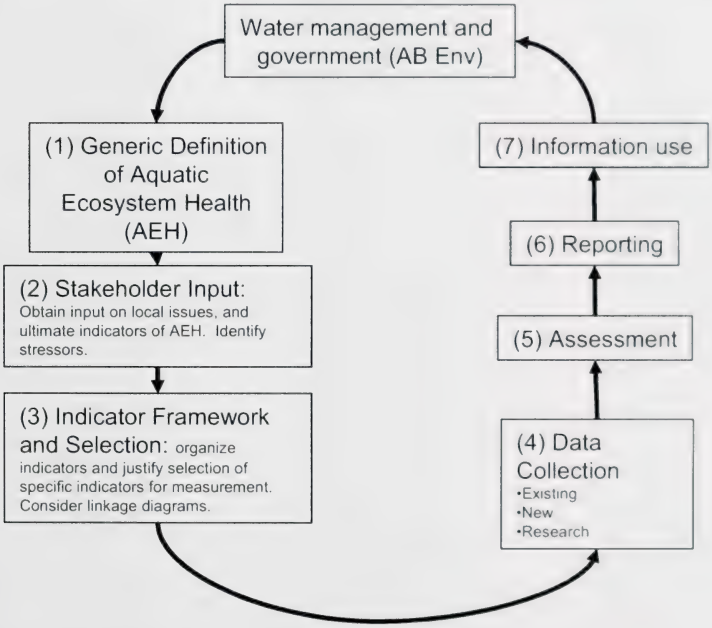


Figure 13. General approach to assessing aquatic ecosystem health.

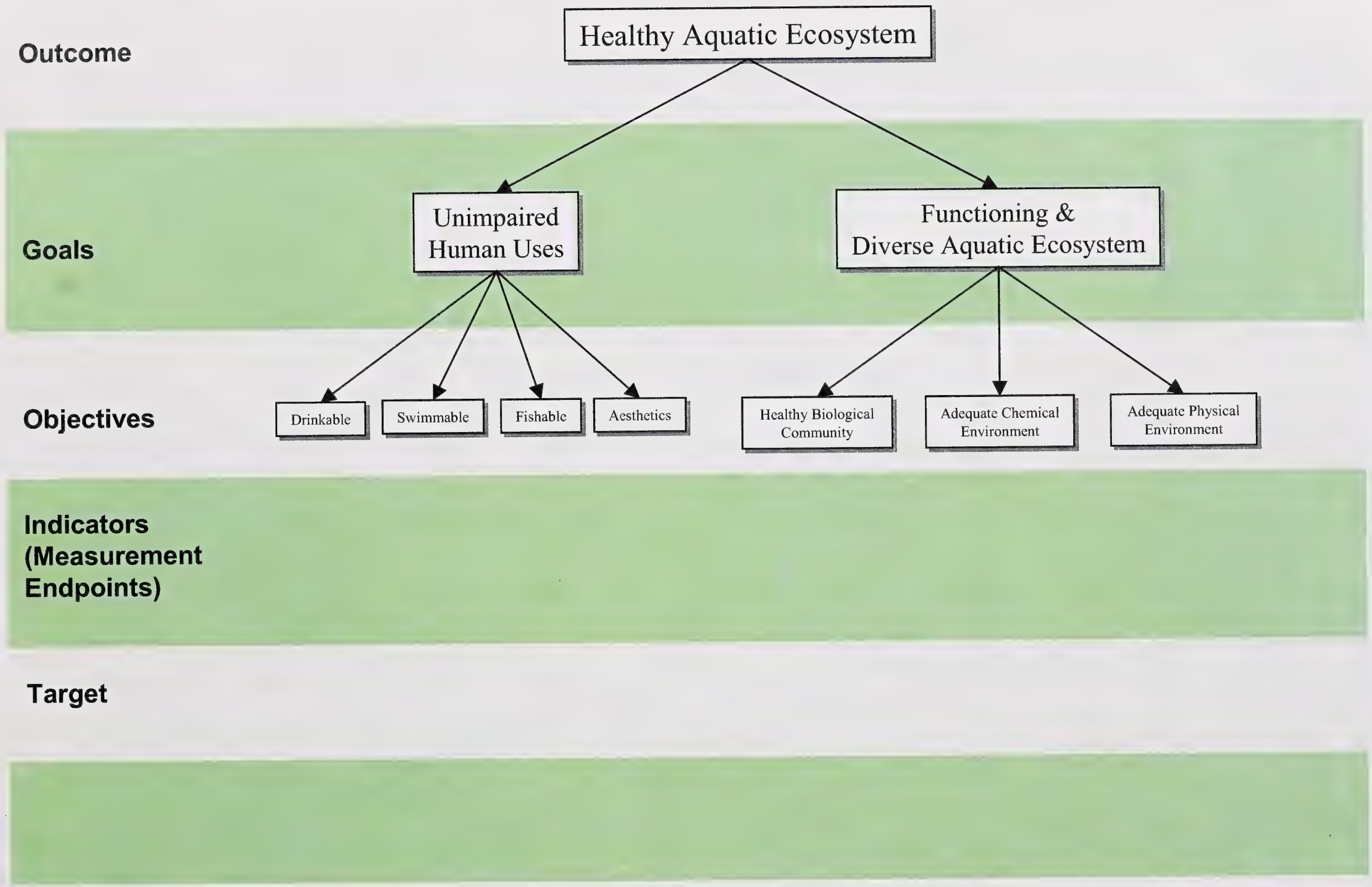


Figure 14. Vision, Goals and Objectives which define Aquatic Ecosystem Health in Alberta.

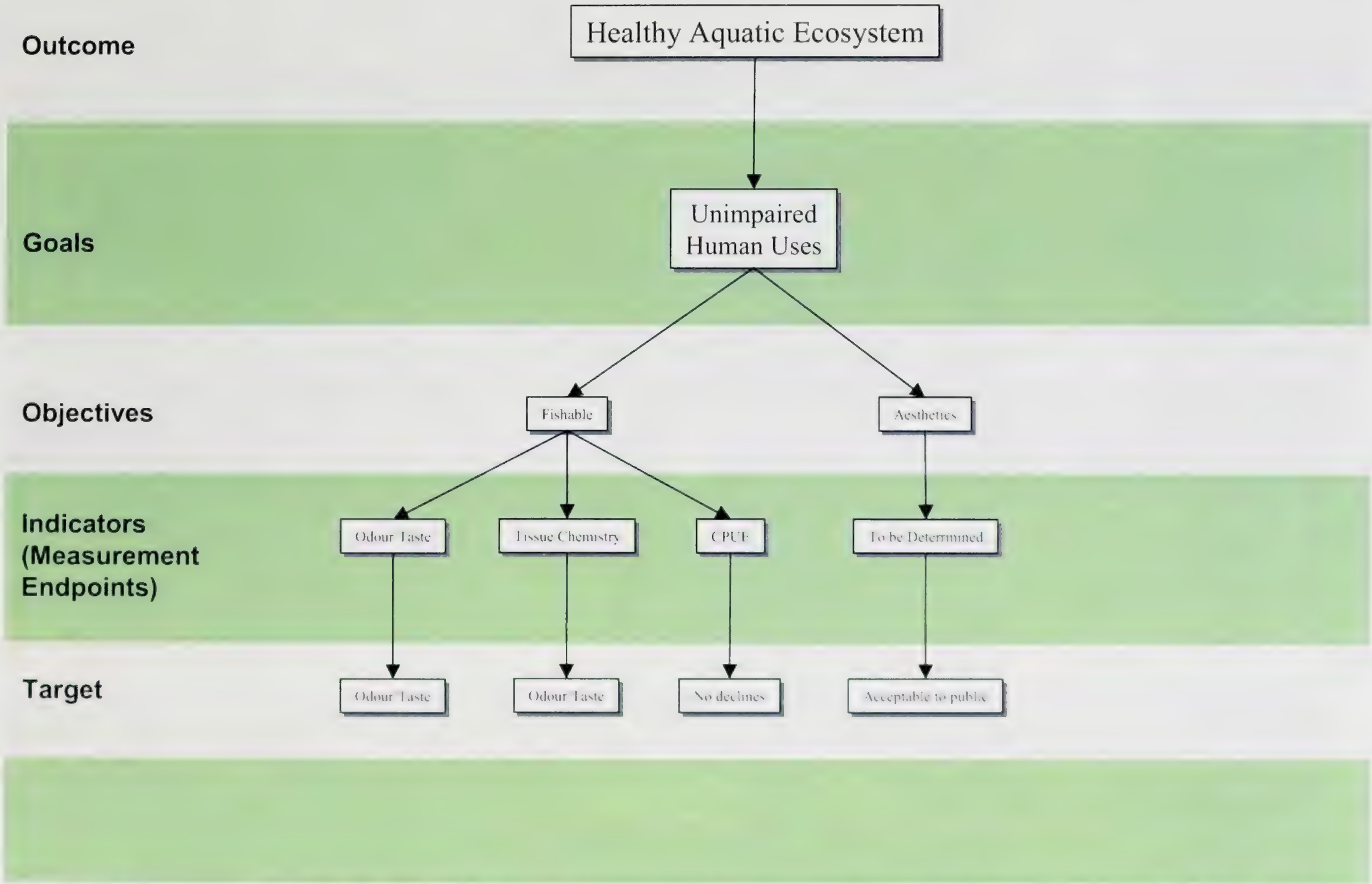


Figure 15. Proposed Objectives under the Goal of Unimpaired Human Uses, as well as Indicators that can be used to evaluate whether ecosystem objectives are being met, and the Criteria against which to judge the condition of an indicator.

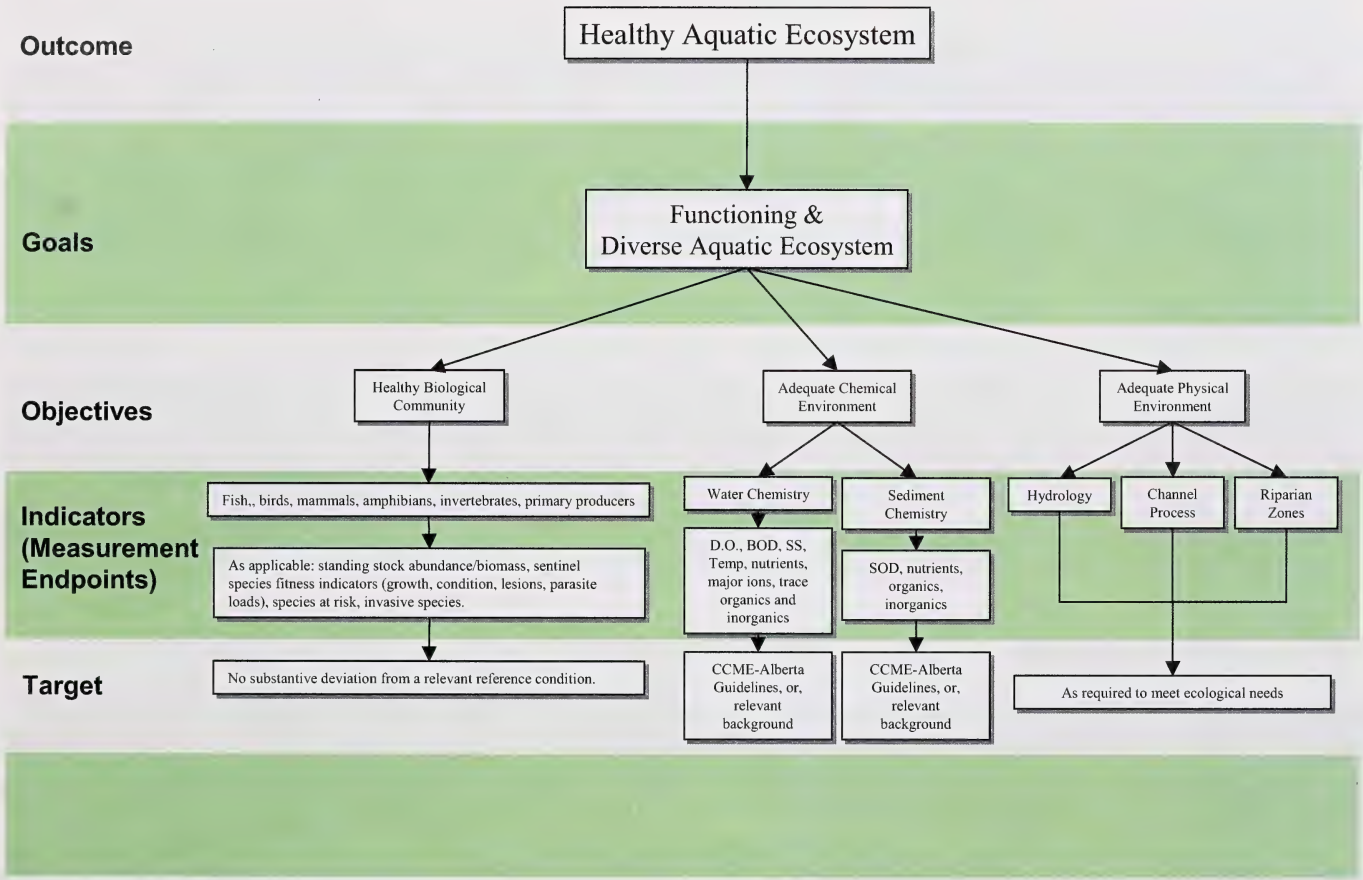


Figure 16. **Proposed Objectives under the Goal of a Functioning and Diverse Aquatic Ecosystem, as well as Indicators that can be used to evaluate whether ecosystem objectives are being met, and the Criteria against which to judge the condition of an indicator.**

Step 4 is the collection of monitoring information and the conduct of research. As part of this initial assessment, it is envisioned that no new data will be collected, and that research, *per se*, will not be conducted. The initial assessment will rely on existing data, whether they originate from hard copy reports or digital databases.

Step 5 is analysis. This scope of work will propose approaches to the analysis and summary of specific kinds of data.

Step 6 is reporting. The scope of work will detail the kinds of information to be provided in hard-copy reports that can be widely distributed. Recommendations for future, more detailed analyses, should be part of the report from the Initial Assessment.

Step 7 is the use of the information, which may be in the form of carrying out more monitoring, taking a management action, or inaction. The various actions require triggers, which should be identified in Step 3.

SCOPE OF WORK FOR INITIAL ASSESSMENT

5.0 SCOPE OF WORK FOR INITIAL ASSESSMENT

This scope of work details the requirements for the Initial Assessment of Aquatic Ecosystem Health for the Province of Alberta. Recommended tasks follow the scheme illustrated in Figure 13. Timelines for the various tasks and subtasks are approximated based on a two-year delivery period. It is assumed that there will be no activity on the Initial Assessment prior to about July 1, 2005, resulting in a total delivery period of about 21 months to the end of March 2006 (Figure 17).

5.1 STEP 1: Generic Definition of Aquatic Ecosystem Health

As in Section 4.0, it is recommended that a pragmatic approach be used in defining aquatic ecosystem health. Generally, healthy environments imply normal aquatic communities, and normal physical and chemical environments. The practical definitions of "normal" are typically based on reference conditions, which is spatially and temporally variable, and depends on the type of aquatic environment (river, lake, wetland). Recommended approaches to quantifying normal and acceptable conditions for the purposes of the initial assessment are provided in the sections below for each of the various recommended measurement endpoints.

5.2 STEP 2: Stakeholder Input/Identification of Issues

As above, stakeholder input is required in order to identify local issues of concern, and to modify the definition of a healthy aquatic ecosystem where it is warranted or needed. There was considerable stakeholder input sought in the initial development of Alberta's Water for Life Strategy, that lead to the formation of the three primary themes of the strategy (Safe, secure drinking water; Healthy aquatic ecosystems; Reliable, quality water supplies) and also to the identification of the need for an assessment of aquatic ecosystem health in Alberta. Given that stakeholders have already been invited to contribute to the Strategy and also that there is not enough time in the Initial Assessment to carry out

a stakeholder consultation process, this step will not be completed. It is anticipated that for the purposes of the Initial Assessment, the input provided by the AENV project team is sufficient for a preliminary definition of AEH in Alberta.

A consultation process could be carried out as part of the reporting of the project, to communicate initial findings. It would be useful to communicate the proposed organizational framework for aquatic ecosystem Goals, Objectives, and Measurement Endpoints, and the criteria (targets) against which those endpoints are being judged. The Public may have useful insight, regionally, regarding what they consider to be important impacts, which may affect regional interpretations.

If a consultation is carried out, it is recommended that it be comprised of workshops held at within specific communities. Following from the previous process for the Water for Life program, consultation could include workshops in up to 10 to 15 communities. To tie into the final reporting, the timing for those workshops should be September to November, 2006.

Issues that this Initial Assessment should consider include both point and non-point source related stresses. Approvals Branch of AENV should be contacted to obtain a comprehensive list of facilities that discharge liquid effluents to surface waters, and to identify water extractions. A list of, and specific locations of municipal discharges is available in the MUD database, while the federal EEM database can provide location information and effluent quality data for pulp and paper mills (Dubé et al., 2004).

Non-point stressors are related to land use. Digital landuse information is available from within ASRD and will include information on forest cover, forest management plans, natural areas, and urban, agricultural, industrial lands.

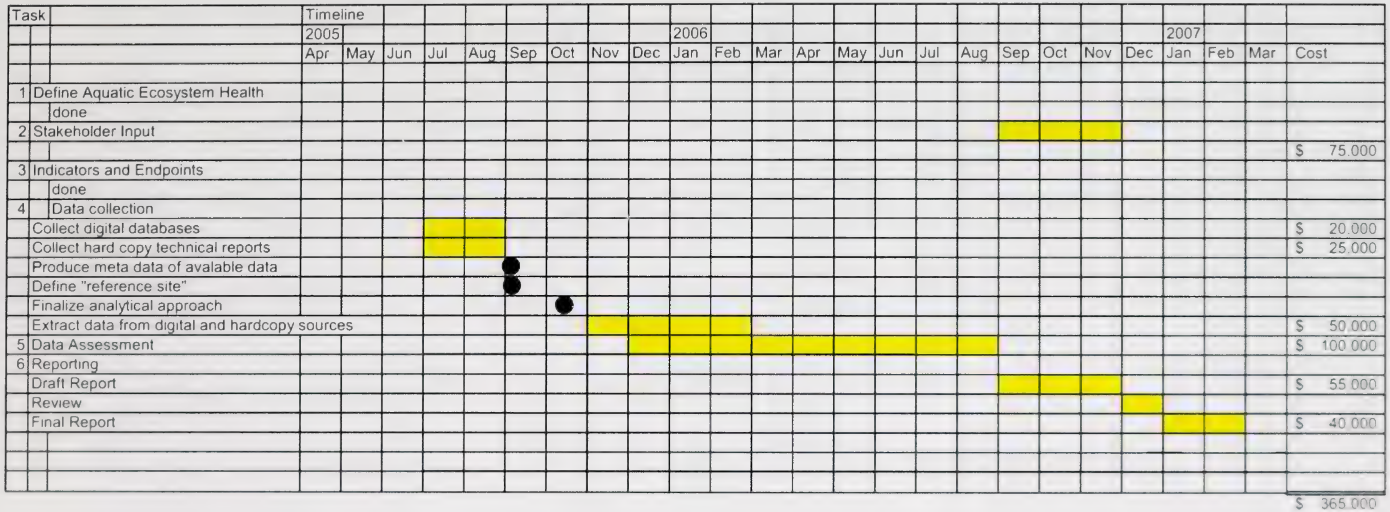


Figure 17. GANTT chart for activities and tasks under the Initial Assessment of Aquatic Ecosystem Health for the Province of Alberta.

5.3 STEP 3: Indicators, Endpoints, and Approach to Assessment

A preliminary list of potential indicators was developed through the team workshop on Feb 9, 2005, and as indicated in Figure 15 and Figure 16. The basic kinds of indicators are identified in those figures. The measurement endpoints associated with each Objective are discussed below, as is the recommended approach to assessment of those endpoints.

In general, it is recommended that data from lotic systems be summarized on a reach basis (reaches to be identified as data become available) as was done in the reviews of northern basins (e.g., NRBSB, 1996; Dubé et al. 2004, 2005). For the purposes of the initial assessment it is recommended that data from lake and wetland systems be summarized on individual bases.

For each endpoint, we recommend that any conclusion that conditions are impaired be determined on the basis of data from relevant reference locations, and comparison to existing guidelines or limits (e.g., CCME, 2001, or AENV chemical guidelines). In general, where an endpoint does not differ from conditions found in reference sites, and is within recognized guideline limits, the endpoint should be considered to be in an acceptable condition. Exceedance of chemical objectives does not always signify a degraded condition because exceedances can be natural. Comparison to a local or regional reference site is, therefore, important.

The selection and interpretation of specific measurable endpoints are discussed below. It is recommended that each of the measurement endpoints be interpreted separately, that the interpretation as to whether an Objective is met be determined via burden of evidence. Also below, we provide guidance on selecting reference sites, and on how to combine the assessments of several endpoints. Finally, we provide guidance on how to interpret the condition of the system based on individual assessments for Biological, Chemical, and Physical Objectives.

5.3.1 Defining Reference Conditions

For the purposes of this Water for Life initiative, reference locations should be minimally impaired, meaning that the landscape has been minimally altered, and that there are minimal point and non-point source discharges to receiving aquatic environments. Definitions for reference sites vary, and the study team is encouraged to develop its own definition early on in the analytical process.

It is anticipated that specific point-source studies (e.g., pulp and paper EEM's) will contain data from site-specific reference sites that are used to contrast with downstream "exposure" sites. Where those upstream reference sites have been demonstrated to be minimally impaired, then they would be suitable for interpreting whether the downstream exposed site is in an acceptable or degraded condition. Where upstream reference sites are degraded because of other upstream discharges, then the site-specific reference site can only be used to determine whether the downstream site has been further degraded by the discharge.

At some point in the *Water for Life* process it would be useful to explore the possible development and use of regional-reference models that relate natural variations in the condition of biophysical endpoints to landscape features. Those models (Figure 11), however, require research efforts and multi-disciplinary teams that include GIS expertise and geo-spatial modeling. Regional-reference models

themselves typically require two years to construct, once all of the data (biophysical endpoints, landscape features) are available. There is inadequate time available to pursue this kind of effort within the proposed time period of the Initial Assessment.

5.3.2 Fishable Objective

There are three potential sets of measurable endpoints for evaluating the Fishable Objective. Studies of odour and taste of fish flesh can be evaluated as per the EEM guidelines for pulp and paper mills (Environment Canada, 2004).

Tissue chemistry of fish flesh should be compared to consumption guidelines provided by Health Canada and other agencies (e.g., Ontario Guide to Eating Sportfish), while an assessment of fish population abundances or catch per unit effort based on creel surveys would benefit the overall assessment of the fishable objective (Table 1).

It is anticipated that fish tissue data will be available in technical reports. Tissue concentrations below concentrations that pose a risk to human health would be acceptable. Concentrations above those guideline concentrations would be considered a potential impairment, whereas concentrations that are increasing over time would be considered unacceptable.

Trout Unlimited, Alberta Conservation and Alberta Sustainable Resource Development should be approached for recent (last 5 to 10 y) creel survey data. Declining catches would be unacceptable.

Table 1. List of measurement endpoints and condition assessment targets for the Fishable Objective

Measurement Endpoint	Recommended Condition Assessment Targets			Potential Data Source(s)
	Acceptable Condition	Potentially Degraded	Unacceptable	
Taste and Odour	No off flavours or odours	Off flavours or odours	degrading	Technical reports
Tissue chemistry	CCME guidelines not exceeded	CCME guidelines exceeded	CCME guidelines exceeded and degrading over time	Technical reports
Fish populations abundances	Not declining		Declining	Alberta Conservation, Trout Unlimited, ASRD
Angler catch per unit effort	Not declining		Declining	

5.3.3 Aesthetics Objective

The aesthetics of surface waters can cover many aspects. CCME (2001) provides guidance on aesthetic properties of water as they relate to swimming and taste. Respecting swimming, attributes to examine include temperature, clarity, turbidity, oil and grease, aquatic plants and nuisance organisms. Respecting aesthetic properties of water (i.e., taste), attributes are listed by Health Canada (2002) and include chloride, sodium, colour, taste and odour, a variety of metals like copper and iron, and a variety of organic compounds. Health Canada guidelines can be used to determine whether there are

potentially any issues. Any data that demonstrate degradation over time would be more compelling evidence impaired "health" with respect to this objective.

Table 2. List of measurement endpoints and condition assessment targets for the Aesthetic Objective

Measurement Endpoint	Recommended Condition Assessment Targets			Potential Data Source(s)
	Acceptable Condition	Potentially Degraded	Unacceptable	
Water taste and odour (parameters as per CCME list)	Within Health Canada guidelines	Exceed Health Canada guidelines	Degrading	AENV water quality database

5.3.4 Healthy Biological Community

A variety of biological measurement endpoints are included in this objective. For a variety of trophic levels they include:

- Indices of community composition (benthos, fish);
- Presence/absence of species at risk;
- Presence/absence of invasive species (e.g., milfoil, crayfish, zebra mussels);
- Standing stock abundance or biomass of keystone species;
- Production (primary, secondary, Chl a);
- Sentinel population performance indicators (e.g., mean age of spawning population);
- Individual performance indicators (e.g., growth, gonad size, liver size);
- Physiological indicators (e.g., MFO induction, reproductive hormone levels); and
- Body burdens of persistent contaminants.

Different trophic levels for which some or all of these kinds of data might be available include fish, invertebrates, algae, and aquatic birds and mammals.

In all cases, the test of whether aquatic ecosystem health has been biologically impaired requires a contrast of data from a reach under evaluation from reaches that are considered, *a priori*, to be in relatively good condition. In many cases, technical reports will contain data and analyses comparing an upstream reference area with a downstream "exposure" area. In other cases, (e.g., RAMP benthic program) regional reference data are used to evaluate benthic invertebrate communities in areas exposed to oil sands development.

There are some generally accepted (used) numeric criteria that can be applied to the kinds of data that are likely to be found in recent technical reports. For surveys of sentinel fish species, differences in mean age of spawners and in growth that are > 25% from reference condition are considered large, while differences in condition factor (i.e., weight at a given length) of > 10% are considered large. Differences (compared to a reference site) that are shown to be getting larger over time, and that exceed those numeric criteria are considered evidence of significantly deleterious effects requiring attention.

Any differences from a reference benthic community that exceed about 2 standard deviations (2 SD) are considered indicative of potential problems, while effects that are large and that are getting larger over time are considered worthy of further attention.

Any study that compares a single reference location against a single "exposure" area runs the risk of declaring an impact has occurred when the observed difference is natural. Studies that incorporate multiple reference areas, therefore, are more reliable than those that do not.

Risks to top-level predators can occur when there are high concentrations of persistent bioaccumulative contaminants in the tissues of prey. CCME (2001) provides tissue residue guidelines for only a few chemicals (DDT total, polychlorinated biphenyls – PCBs, toxaphene). Exceedance of those residue guideline levels are considered to potentially pose a risk to mammals and birds. Aquatic birds and mammals have little or only occasional contact with sediments, so sediment quality guidelines are not good indicators of stressors to bird and mammal populations. DDT, PCBs and toxaphene are rarely detectable in water, but are highly bioaccumulative. These tissue residue guidelines are, therefore, important to consider when evaluating the health of the aquatic environment. Where these concentrations are shown to be exceeded in fish tissues, fish eating birds and mammals should be considered at potential risk and the health of the system potentially degraded. Where these concentrations are shown to be increasing over time, the condition of the system should be considered degraded.

To address the biodiversity objective, we recommend that the Initial Assessment consider an evaluation of the presence/absence and population abundances of species at risk. Data for the assessment are expected to be available from ASRD's BSOD data base, but may also be available in technical reports. Where SARs are present in viable population abundances they should be considered to be in good condition. Where population abundances have been demonstrated to be in decline, or where SARs have been demonstrated to be extirpated, they should be considered to be in a degraded condition.

The presence/absence of invasive species is expected to be available in the ASRD BSOD data base. Surface waters in good condition will not have invasive species, while those where species have "invaded" routinely over time should be considered to be degraded.

Table 3. List of measurement endpoints and condition assessment targets for the Biological Objective

Measurement Endpoint	Recommended Condition Assessment Targets			Potential Data Source(s)
	Acceptable Condition	Potentially Degraded	Unacceptable	
Sentinel fish populations: growth, condition, age	Not different from reference reach	>25% differences in growth and age, >10% differences in condition	Degrading over time	Technical reports
Benthic community indices of composition including diversity	Not different from reference	> 2SD difference	degrading	Technical reports
Tissue chemistry	Within CCME limits	Exceed CCME limits	degrading	Technical reports
Species at risk	Present and in good numbers	Present in low numbers	Declining	ASRD, BSOD
Invasive species	none	present	Increasing numbers of species	ASRD, BSOD

5.3.5 Adequate Chemical Environment Objective

The evaluation of water and sediment quality requires the consideration of both CCME (2001) and AENV chemical quality guidelines, and of relevant reference conditions. Where the existing chemistry is within chemical guidelines, the chemical environment can be considered to be in good condition. Where guidelines are exceeded, and where the chemistry of an aquatic environment is shown to be significantly different from relevant reference locations, then that area may be considered impaired.

Both water and sediment chemistry present two significant challenges. First, though the province routinely collects extensive water and sediment quality data, it is unclear what the natural background concentrations are for many parts of the province. Paleolimnological data from cores may be useful for determining whether the chemistry of lake environments has been degraded from pre-European settlement.

Water quality parameters that might be included in the assessment of the chemical environment include:

- Dissolved oxygen, COD, BOD, suspended solids, temperature;
- Nutrients (N, P, C) and associated variables (ammonia);
- Major ions;
- Metals; and
- Organic contaminants (pesticides, PAHs).

Sediment quality parameters might include:

- SOD;
- Nutrients, organic content;
- Metals; and
- Organic contaminants (pesticides, PAHs).

Table 4. List of measurement endpoints and condition assessment targets for the Adequate Chemical Environment Objective

Measurement Endpoint	Recommended Condition Assessment Targets			Potential Data Source(s)
	Acceptable Condition	Potentially Degraded	Unacceptable	
Water chemistry	Within CCME and AENV limits	Exceed CCME and AENV limits and different from reference	Exceed CCME and AENV limits, different from reference, degrading	AENV water quality database
Sediment chemistry	Within CCME and AENV limits	Exceed CCME and AENV limits and different from reference	Exceed CCME and AENV limits, different from reference, degrading	AENV water quality database

There is expected to be a large amount of chemical environment data, providing a variety of options for analysis and interpretation. The large number of parameters will require some form of data synthesis. With many parameters, the likelihood that any will naturally exceed published guidelines is high, or be shown to differ from a reference condition, so exceedances and differences need to be interpreted cautiously. It may be necessary to use multivariate methods (clustering, ordination) to synthesize the results from several parameters at a time, in comparisons against data from reference sites.

Analytical method changes can affect detection levels and mean chemical concentrations. Some consideration of analytical methods will be necessary to ensure that observed spatial and temporal variations are not artifacts. In a similar analysis of spatial trends in water quality in Ontario, Kilgour et al. (2002) selected data post 1995 because methods for the analysis of metals concentrations biased the data in years prior to 1995. So, the time series of data to use in this initial assessment will, in part, be determined by method changes that may or may not have imposed biases in the data.

It is recommended that the use of multivariate methods for quantifying large-scale (i.e., province-wide) spatial variations in surface water chemistry and sediment chemistry be explored. Such analyses could be conducted separately for riverine, lake and wetland habitats, where the data are available. Where it is possible to identify sets of sites as representative reference areas, then multivariate analyses can be carried out to contrast variations in reference sites to variations in other sites (Dodds et al., 2002).

5.3.6 Adequate Physical Environment Objective

There are a variety of physical habitat endpoints that could be included in this overall assessment, however, of most importance in the Province at this time is low flows in some of the southern basins. A variety of studies on instream flows have been carried out and demonstrate that the flow requirements for fish and other ecological indicators are not being met. The results of those instream flow studies should be captured in this overall Initial Assessment. It is recommended that where the ecological instream flows are not being met, that flows be considered potentially impaired, and where there is evidence of declining flows they be considered unacceptable.

The minimum instream flows are the flows that meet the requirements for fish habitat, water quality, riparian zones and channel maintenance. Detailed studies are required in order to complete an analysis for any one river reach, and is outside the scope of this initial assessment. This initial assessment rather, should attempt to capture the results of instream flow needs studies to provide a snap shot of the existing condition. Recommendations for future instream flow needs analyses should be an outcome of the initial assessment.

5.4 STEP 4: Data Collection

Data will be collected for the indicators and measurement endpoints identified in Figure 15 and Figure 16. Data are anticipated to be in a combination of digital databases and hard copy reports. Within the province of Alberta, there are a few key databases that will need to be mined for data to carry out the Initial Assessment. These include:

Alberta Environment Water Quality Database containing concentrations of nutrients, metals, and organics concentrations in water and sediments.

Fisheries Management Information System (FMIS) containing fish and fish habitat data derived from various data collections within Alberta. The database is considered to be in a developmental state and is managed by Alberta Sustainable Resource Development (ASRD).

Biodiversity/Species Observation Database (BSOD) containing data on the location and number of rare and sensitive wildlife species in Alberta. The database is maintained by ASRD and the Alberta Conservation Association (ACA).

Other information and data should be obtained from:

Consultant reports written on behalf of companies pursuant to Certificates of Approval and other legislation.

Environmental Effects Monitoring reports. Pulp mills and oil sands developers (RAMP) prepare reports frequently, reporting on water and sediment quality, and benthic and fish communities in response to requirements under the Fisheries Act or other legislation.

Government research and reports including but not limited to the Northern River Basins Study, Northern River Ecosystems Initiative, and other special studies.

University research including but not limited to programs such as TROLLS and studies under the Sustainable Forest Management Network.

Non-government organizations such as Ducks Unlimited and Trout Unlimited

Stantec Consulting has been contracted to develop a complete list of potential aquatic-environment data sources that could be used to generate a knowledge base for this Initial Assessment.

Data will be compiled on a drainage basin basis (and at a reach scale where relevant), and assessments of aquatic ecosystem health will be conducted on a reach scale where possible. Reaches will be identified as part of this task, after data have been compiled.

5.5 STEP 5: Data Assessment

The approach to assessing (interpreting) data has been described in the above section. The assessment will, however, have to consider data quality, and the time period that will be covered. Data quality could change for some parameters (e.g., trace metals; as per Kilgour et al., 2002), and so some consideration for limiting the time series may be required. Though there will be obvious methodological changes for some parameters (e.g., benthic community survey methods), the focus of the initial assessment should be on data collected with consistent methodologies. The implications of method changes to water and sediment quality data should be evaluated prior to determining the time horizon to cover in the initial assessment. For some parameters (total phosphorus), for example, method changes will not influence the interpretation of condition as much as for other parameters (e.g., trace metals).

To the extent that resources permit, data analysis should be conducted on a geo-spatial basis, so as to be able to quantify aquatic ecosystem health across the province for the attributes that will be analyzed.

An additional function of the data assessment stage will be the identification of data gaps across the province that hinder the ability to adequately quantify aquatic ecosystem health or to quantify stressors imposed upon aquatic ecosystem by different service sectors (e.g., agricultural developments, urbanization, deforestation, etc.). These data gaps will be used in the interpretation stage to make recommendations for directed or long-term monitoring to better quantify effects to aquatic ecosystems in Alberta.

5.5.1 Integration

The assessments by reach, wetland and lake will summarize the condition for each of the measured endpoints for which there were data. It is anticipated that the results will be portrayed visually using maps as in the NRBSB (1996) summary, or as in Dubé et al.'s (2004, 2005) assessment of cumulative effects in the northern basins of Alberta (Figure 18). Conclusions as to whether each of the five Objectives (fishable, aesthetics, biological, chemical, and physical) would be provided for each river reach for which there are data. Integration of each of those five assessments into one overall assessment is not necessary, because each provides unique in formation.

Most of the objectives will be addressed by multiple measurement endpoints within a reach, lake or wetland, so some consideration on how to integrate those individual endpoints is required. In general, it will be difficult to combine results in a fully quantitative way. Rather, deriving a conclusion for any one objective will require professional judgment including subjective weight of evidence. In this regard, this initial assessment then will incorporate elements of best judgment, founded on data (science).

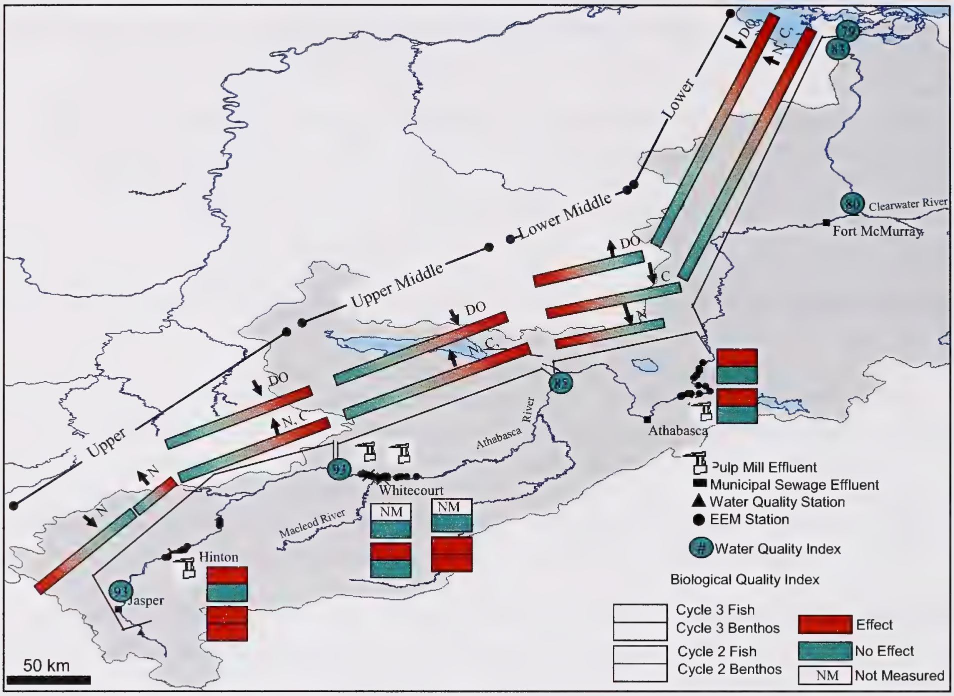


Figure 1. Example visual display of results as part of the Initial Assessment. From Dubé et al. (2004).

5.6 STEP 6: Reporting

The outcome from the Initial Assessment will be a technical report that summarizes the stressors and condition of aquatic resource endpoints across the province. The report will be used as an initial step in quantifying the state of aquatic ecosystem health in Alberta. It will synthesize available information relating to stressors imposed upon aquatic ecosystems as well as ecosystem response variables that give indications of the state of aquatic ecosystems across the province. The report should provide an overview of general health across the province, followed by detailed analysis of ecosystem health by region (ecoregion or drainage basin) and by stressor type (i.e., municipal, agriculture, forestry, oil sands development, etc.). Ideally, the regional analysis of ecosystem health will quantify the cumulative effects of multiple stressors within a drainage basin, whereas the stressor-based approach will provide an overview of the general effects of different service sectors on aquatic ecosystem health.

The identification of regional 'hot spots' (i.e., regions that have degraded or degrading aquatic ecosystem health) in the province or human stressor 'hot spots' (i.e., human stressors that consistently lead to degraded or degrading aquatic ecosystem health) can then be used to target future monitoring and management activities within the province. A discussion surrounding data gaps in terms of both ecosystem based indicators and stressor based indicators is also needed that can be further used to guide future monitoring programs.

It is recommended that the report have a table of contents with the following:

1. Introduction
2. Environmental Overview
   a. Municipal
   b. Agriculture
   c. Forest Industries
   d. Petroleum
   e. Mining
   f. Transportation
   g. Dams and Reservoirs
3. Use of Aquatic Resources
   a. Consumptive Uses
      1. Municipal
      2. Agricultural
      3. Industrial
   b. Non-Consumptive Uses
      1. Recreation
      2. Commercial Recreation
      3. Commercial Fishing
      4. Trapping
      5. Ecological Uses
4. Aquatic Ecosystem Health
   a. Approach and Methods
      1. Indicators/Endpoints
      2. Data Sources
      3. Triggers for Assessment
   b. Assessments by Reach, Lake and Wetland
5. Summary
6. Recommendations

5.7 STEP 7: Information Use

This is outside the scope of the Initial Assessment.

5.8 Costs

The estimated costs for this Initial Assessment are expected to range between $290 and $365K, depending on whether a consultation process is included. Costs are broken down as in Figure 17.

6.0 CLOSURE

This Plan for the Initial Assessment of Aquatic Ecosystem Health in Alberta was developed with input from several organizations and their staff. We thank Rolf Vineburg (University of Alberta), Anne-Marie Anderson, Leigh Noton, Colin Fraser, and David Trew (AENV), Dave Borutski (ASRD), Monique Dubé (NWRI), Michelle Tait, Mike Bartlett and Scott Stoklossar (JW) for their input.

Yours truly,

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